Repeat Surveys to Evaluate Seasonal Variability in Seafloor and Shallow Sub-surface Acoustic Properties, Shallow Water Gulf of Mexico

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LONG-TERM GOALS

To investigate the seasonal variability in seafloor and shallow sub-bottom acoustic properties in the shallow water Gulf of Mexico. We chose three sites for this purpose. The sites, and their primary objectives, are:

MURI Fluid-Mud site, Louisiana. Acquisition of a baseline geophysical data set in summer 2007 along the two primary transects identified as the focus of ONR-sponsored research as part of the Fluid-Mud MURI. Groundtruthing of the acquired acoustic/geophysical data with extensive coring, including additional sites where our colleagues from NSP/SIO deployed their waves/pressure sensors. The direct sampling measurements (grain size, viscosity) will add to their wave model. The area was re-surveyed in winter 2009, with additional survey lines acquired over new MURI instrumentation sites.

West Delta area, Louisiana. An area tightly related to the offshore industry, we chose the West Delta / South Pass area offshore the Mississippi River bird's foot delta for our study. Specifically, a survey conducted in the area of the West Delta 109 pipeline, which broke during the 2005 hurricane season, imaged numerous mud flows, with some areas characterized by 6 to 10 m of net accumulation over a 20 year period. The SS Virginia shipwreck occurs in the field area, and had been mapped previously on three occasions, showing that the mud flow in WD109 moved more than 400 m in the 2005 event. Previous mapping in the area did not extend to a hypothesized source of the mud flows at the West Pass channel outlet and/or the designated Corps of Engineers dredge dump location. Our goal at this site was to determine seasonal variability due to Mississippi River sediment delivery and to examine the connection between the previously mapped mud flows, possible sources, and the connection to anthropogenic influences. We documented temporal changes between the 2005/2006 industry survey, the 2007 ONR survey, and our last survey of February 2009, which showed that the mud flows in WD109 moved again during the 2008 Hurricane season (Gustav, Ike).

Panama city, Florida. Previous studies in the SAS Target Area test bed offshore Panama City, Florida, documented changes in the ability to 'see' targets placed in the field area. The causes of this variability

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to map targets, and the causes of the seasonal variation in acoustic properties, were unknown, and are the focus of our research. We cored the survey area extensively to groundtruth the acquired acoustic/geophysical data. We re-acquired survey data over the same areas surveyed previously in February, 2009, to search for seasonal changes.

OBJECTIVES

Our objective in all study areas is to increase our understanding of the variability of seafloor and shallow sub-surface acoustic properties that impact the ability to identify anthropogenic objects in the nearshore environment. Specifically, the present work is relevant to enhancing ONR's understanding of surface and subsurface seafloor geological characteristics, including geoacoustical and geotechnical properties. We are interested in determining differences in seafloor acoustic signatures between frequencies (same area, same time), and between seasons (same area, same frequency, different time). Our areas of interest are shown in Figure 1.

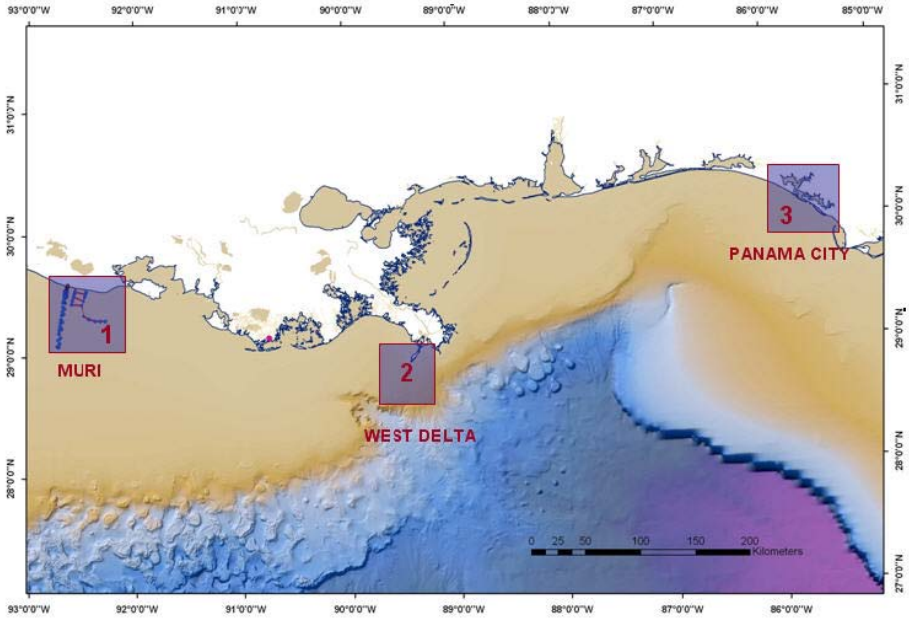

Figure 1. Surveyed areas in June 2007 and February 2009 in the Gulf of Mexico. Area 1 corresponds to the MURI site, Area 2 corresponds to the West Delta site, and Area 3 corresponds to the Panama City site.

APPROACH

We conducted one acoustic/geophysical field program in June 2007, three coring programs during February-April 2008, and another acoustic/geophysical field program in February 2009. All the geophysical instruments acquire data simultaneously, using the same platform, the same navigation suite, and the same motion reference unit.

We mobilized and demobilized out of the LUMCON facility, where the UNOLS vessel R/V "Pelican" is based. We mounted two multibeam systems of different frequencies (95 kHz, and 300 kHz), both

capable of bathymetry and sub-sampled backscatter acquisition, on either side of the research vessel. We towed a dual frequency Benthos Datasonics SIS-1000 with a side scan sonar (90-110 kHz frequency) and sub-bottom profiler (2-7 kHz frequency). The team mounted the EM3002 on the port side and the EM1002 (heavier and bulkier, 2007) or the EM710 (2009) to the starboard side. Note that we were aware of the possibility of interference/s of all the transducers as they were mounted close to each other and the signature of any interference is being evaluated in post processing. We kept all of the geophysical and vessel parameters as constant as possible in order to measure the variability in the acoustic character of the seafloor and shallow sub-surface between systems (frequency) during the same deployment. We kept the same kit (all systems except using the EM710 instead of the EM1002 due to availability), down to the individual multibeam heads, mounts, motion reference unit, software, etc. during the February, 2009, follow-up cruise in an attempt to isolate the differences in measured seafloor response between this and the previous survey to the actual variations in seafloor acoustic properties over time.

We groundtruthed the indirect datasets with three coring programs between February and April 2008. We used surficial grab samplers and box cores to obtain the samples, described them and took pictures onboard, and refrigerated them until they were sent to the USGS laboratory for the grain size analysis. Some of the samples from the Fluid-Mud MURI site were also sent for viscosity analysis to Johns Hopkins University, which will compliment the wave measurements that the NSP/SIO group is working on. The laboratory sediment analysis datasets are currently being interpreted.

RESULTS-WORK COMPLETED

Fluid-Mud MURI area, Louisiana:

Within the frame of the ONR research program: the “Mechanism of Fluid-Mud Interactions Under Waves” (c.f.: http://www.ce.jhu.edu/dalrymple/MURI), we acquired geophysical/acoustic datasets along several transects off the coast of Louisiana, west of Atchafalaya Bay (Figure 2). Following the acquisition of geophysical data in summer 2007, we provided an ArcGIS / ArcReader geophysical/acoustic baseline project for all MURI researchers. Following the 2007 geophysical survey we participated in two coring cruises in the area in order to groundtruth the geophysical / acoustic datasets and also to acquire samples so that the Naval Postgraduate School (NPS) scientists could add the size grain component to their models.

In February, 2009, we re-acquired the two long lines, as well as a portion of the inner shelf that had been surveyed in 2007. Following the 2007 survey, MURI researchers identified an additional area of interest east of the original proposed transect lines, and NPS deployed a number of sensors in this area. In 2009 we surveyed several transects within this new area of interest. These data will be combined with the previous survey data and the core data, and the project GIS will be re-issued to all MURI researchers. In addition to the geophysical surveys for sediment processes / variation and classification, in the February 2009 survey we responded to a request from our colleagues from NSP/SIO (Dr. Tom Herbers group) and searched for one of the NPS sensors lost prior to their last field program. We identified several possible objects and have passed the information along (see figure 2).

The geophysical and acoustic data of 2009 (EM 3002 and EM 710 data) are being processed now and in FY2010 we will compare these data with the 2007 survey data and groundtruthed cores. All the final processed data will be available to all researchers in 2010.

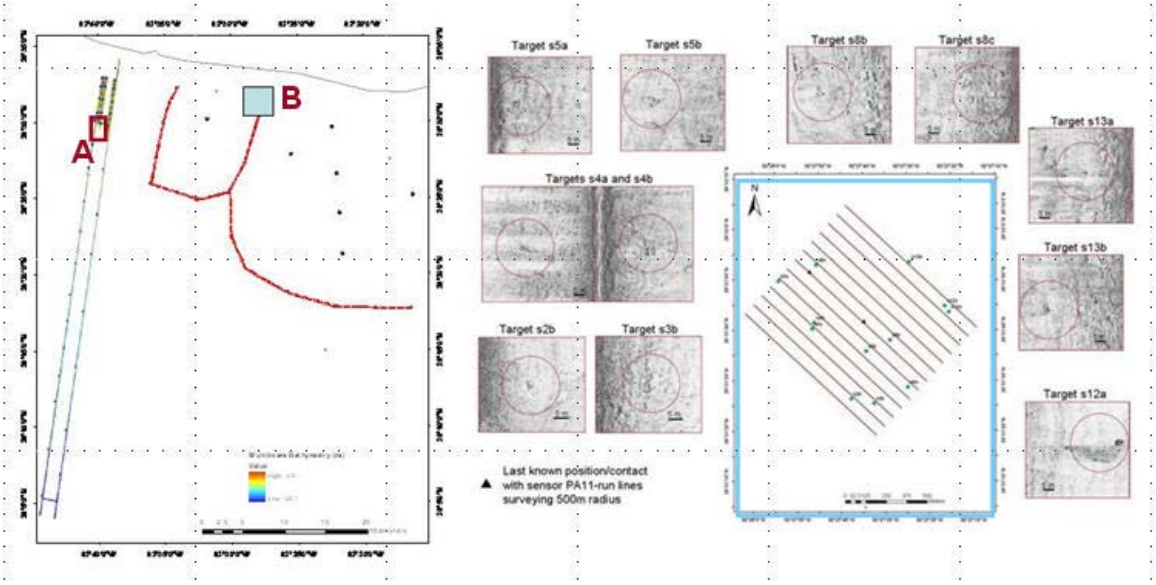

Figure 2. MURI area of interest (last geophysical program in Feb09 in red lines and squares A and B). The blue box B indicates the search area for the NPS sensor (right). Several targets were found and all the information was given to the NPS colleagues.

West Delta 109 Mudflow Region:

The West Delta 109 region is in the part of the Bird's Foot Delta that experienced significant damage to oil industry pipelines and platforms in the 2005 Hurricane seasons (Katrina and Rita). Industry-sponsored surveys following the hurricanes showed that the seafloor here was rugose, and comprised of numerous mudflows. The ONR sponsored surveys in 2007 and 2009 gave us an opportunity to examine part of the mud flow region in detail in order to determine how fast the mud flows are moving. Note that in 2007 and 2009 we also re-surveyed the wreck site of the S.S. Virginia, which we can use as a strain marker in the mud flows to examine not only translation but rotation. In 2009 we also used Lumcon's ROV to obtain photographs and videos of the wreck (see figure 4).

Figure 3 shows a portion of the upper mud flow region re-surveyed in February 2009. This is a difference grid compared to the June 2007 survey. Lighter colors indicate that the seafloor here is shallower in 2009 than in 2007, whereas darker colors indicate that it is now deeper. Note that distinct shapes of what are interpreted to be rigid blocks 'floating' in the mudflow can be seen in the difference grid. This suggests that these blocks are moving over time (if they were not moving, there would be no difference between the grids, and they would be grey, with no discernable boundary). The central large block appears to be 1.5m shallower in 2009 than in 2007, which would indicate inflation of the mudflow in this region. Our plan is to outline all identifiable blocks in both the 2007 and 2009 data sets, and then see if we can identify the location of the same block in both data sets. We will identify the centroid of each identifiable block, and will evaluate the vector joining them (amount of translation, June 2007 to Feb 2009). We will also examine block rotation.

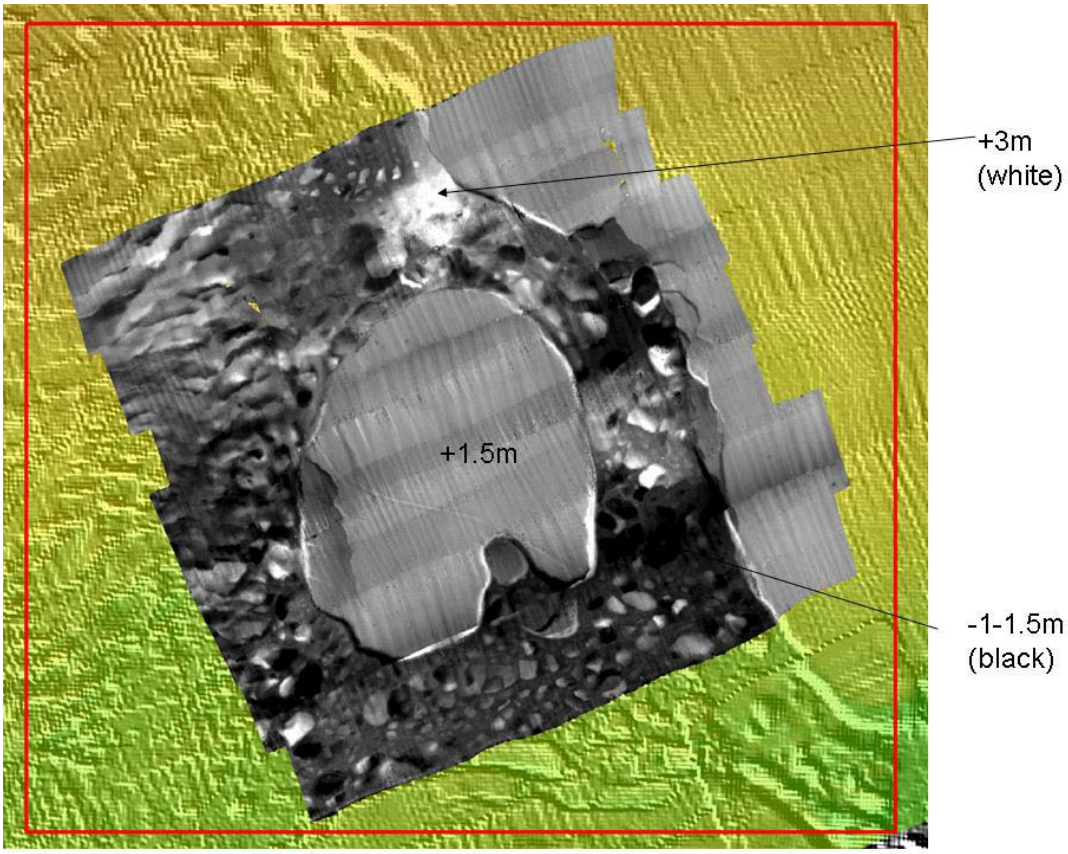

Figure 3. Area targeted to be resurveyed in 09 off West Delta mud flows. In white, areas of net accumulation are shown (bathymetry 2009-bathymetry 2007) and in black, areas of mass removal (erosion, deflation, or translation). In this case its seems the central block has been uplifted by 1.5m, and the surrounding seafloor has 'lost' 1 m to 1.5 m of sediment.

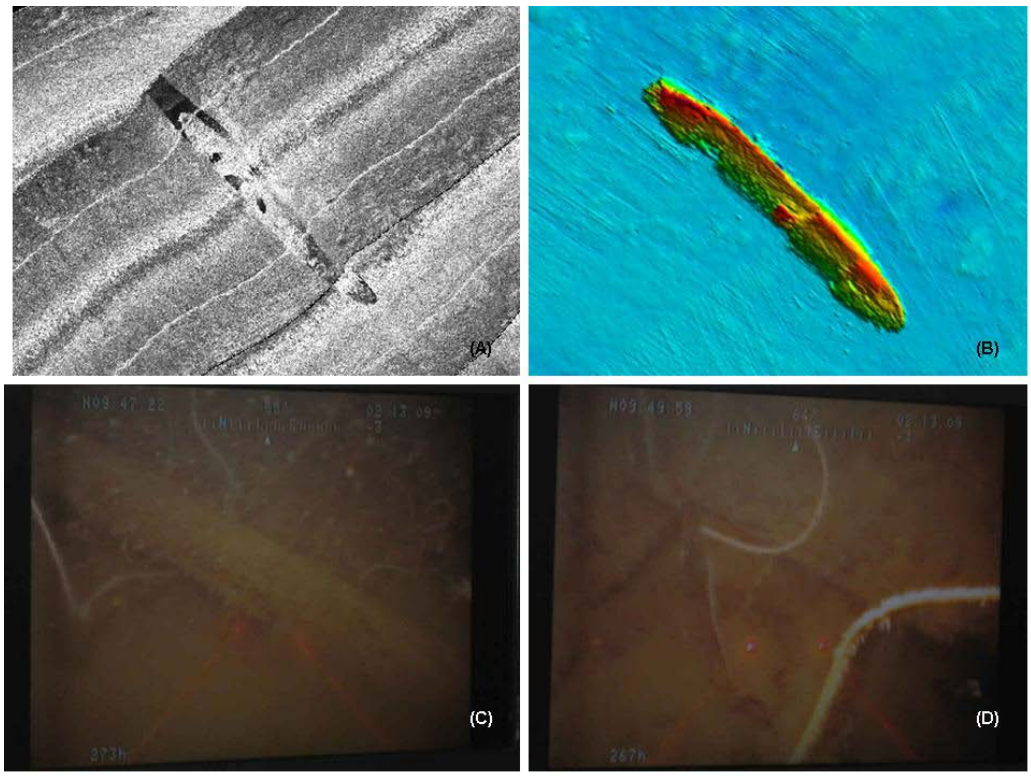

Figure 4. Wreck site S. S. Virginia. Side scan sonar mosaic shown in 5A, multibeam image (300 kHz) in 5B, ROV visuals of the wreck in figures 5C and 5D.

We are carrying out a similar study with the SS Virginia wreck location. Preliminary analysis suggests that it moved ~20 m between June 2007 and February 2009, with a slight clockwise rotation as the SE end has moved farther south than the NW end.

The geophysical and acoustic data of 2009 are being processed now to the integrate fully with the 2007 data. The EM 710 datasets are being evaluated now to study the differences between frequencies as well.

Panama Citym Florida, Shallow Sites:

As part of their ongoing program for the detection of anthropogenic objects, Navy researchers have been placing objects at known locations offshore Panama City (PC), Florida, in water depths ranging from 50 to 210’ (16 to 70 m). Working closely with the Navy team in PC in 2007, we identified five areas to be surveyed. We deployed two multibeam systems of different frequencies (95 kHz and 300 kHz) and a side scan system in June 2007. Surficial cores were obtained in January 2008 to ground truth our geophysical datasets. These sites were re-surveyed in February 2009, again with multiple multibeam systems and a side scan. Just prior to the February 2009 cruise navy researchers identified some additional sites to survey based upon their have difference in lithology (coral) at the seafloor. Unfortunately, we only had time in the cruise to re-survey the original sites (one of the primary objectives of this research), and as such, we had no time for the proposed new sites in the 2009

program. Depending on ONR / Navy interest, we would be very interested in returning to PC to both re-survey the original sites, and to survey these new locations.

While calibrating the systems in the PC area, we surveyed a wreck that was not on the nautical charts and was later identified as the S.S.Strength, used for NAVY training (see figure 5).

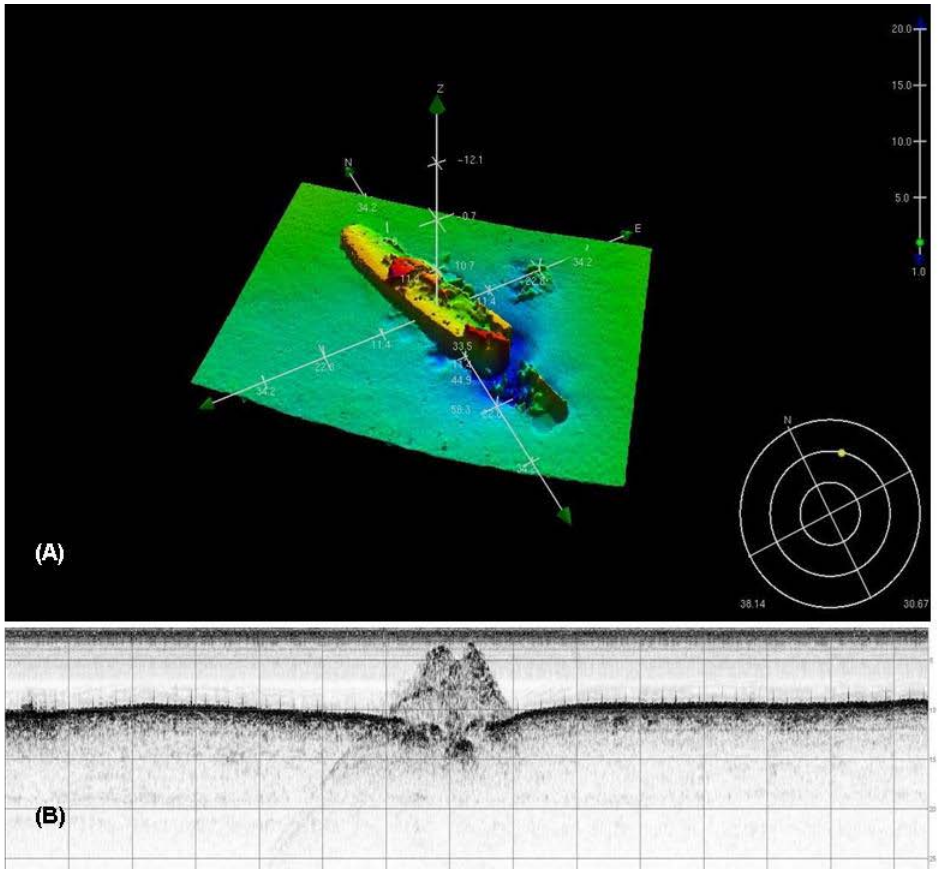

Figure 5. EM 3002 multibeam image of the S.S. Strength (300 kHz, A), and sub-bottom profiler over the wreck (B) off Panama city.

Preliminary analysis of the co-located data sets shows differences between the June 2007 (summer conditions) and February 2009 (winter conditions) surveys. The images shown below are difference grids, where we subtracted the seafloor bathymetry obtained from the 300 kHz multibeam (EM 3002) of both datasets (50 cm resolution). These grids illustrate areas of sediment removal / erosion (light colors; negative numbers) and areas of net accumulation, where the seafloor is now shallower than in 2007 (darker colors; positive numbers). Examples are shown in figures 6.

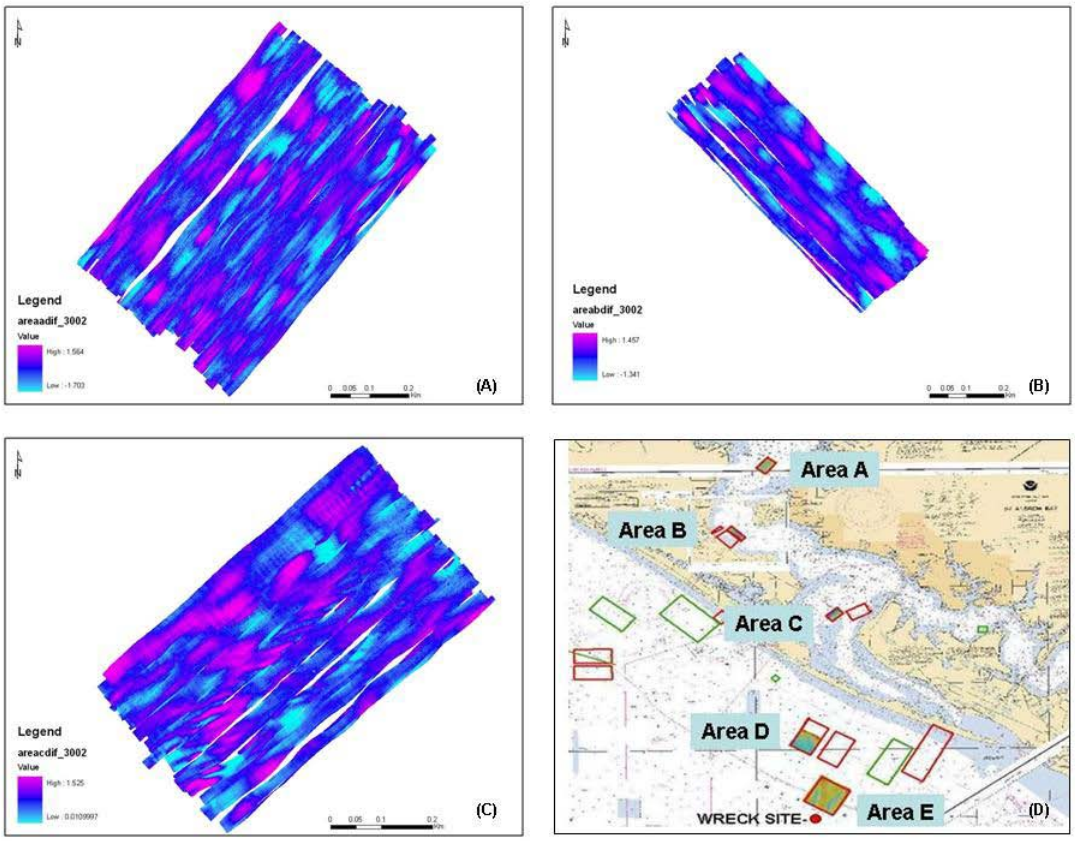

Figure 6. Area A image showing the most erosion of all the sites between 2007 and 2009, being the 'high' values the net accumulation and the 'low' ones, the net erosion (A); Area B image showing difference of sediment (m) (B); Area C showing the differences in a wavy seafloor (C). Map of the sites of interest off Panama city with areas A to E and wreck site (D).

All three sub-areas shown above show variation between summer 2007 and winter 2009. The largest range occurs in Area A, which the cores in January 2008 showed to be the muddiest site, indicating that this site has the most seasonal variation, and also the highest erosion (see figure 6A). The EM 710 datasets are being evaluated now to study the differences in this 90-100 kHz system as well.

IMPACT/IMPLICATIONS

The impact of the ongoing research is different in each area. In the Fluid-Mud MURI location, the geophysical/acoustic dataset and groundtruthing provide a comprehensive baseline and geophysical context for studies for all MURI scientists. All of the seafloor data are georeferenced, combined with all provided MURI instrumentation locations, and provided to all MURI scientists as a GIS. This GIS is being updated as coring/groundtruthing information comes in, and will be further updated with the February 2009 survey data and re-issued to all interested MURI scientists. As an example of this collaborative effort, multibeam datasets have been shared with WHOI (Dr. Peter Traykovski and colleagues), and the sediment analysis data with NSP/SIO (Dr. Tomas Herbers and colleagues) and Johns Hopkins University (Dr. Robert Dalrymple).

The West Delta area has proven to be interesting as we have found a possible anthropogenic source/cause for a component of at least one of the mud flows. Analyzing the February 2009 data in the areas re-surveyed will tell us how the 2 hurricane seasons affected the area of mudflows. Also, by revisiting the SS Virginia wreck we determined its February 2009 location relative to the 2007 (and older) locations as this wreck provides a strain indicator of the mud flow's movement. This will give us an idea of the rate at which these features move so that we can better understand the impact of these flows on existing or future seafloor installations. The collaboration with the LUMCON staff (donating ROV time for studying the wreck site) has been a productive one since our first survey in 2007.

The datasets off the Panama city sites show bathymetric variability between 2007 and 2009. Preliminary analysis of the 2009 data show differences between frequencies. We expect to integrate all datasets (acoustic/geophysical surveys and coring data) in the upcoming year and have an updated GIS available to share with colleagues at Panama City, included Ray Lim and Kerry Commander.

For the core datasets, our ongoing collaboration with USGS Menlo Park (CA) scientists (Dr. Tom Lorenson) has proven to be successful for both parties. We have been actively collaborating with Dr. Lorenson for years in our ONR-funded research efforts, presenting findings at conferences, writing papers, and collaborating on the field.

PUBLICATIONS

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